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AN INDUSTRIAL WASTE GUIDE TO THE SYNTHETIC
TEXTILE INDUSTRY

Public Health Service
Washington, D.C.

1965

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5285 Port Royal Road, Springfield Va. 22151

an Industrial Waste Guide to the

Synthetic Textile Industry

*Prepared by the Committee on Stream
Sanitation Technology of the American
Association of Textile Chemists and
Colorists in cooperation with the
National Technical Task Committee on
Industrial Wastes*

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Public Health Service
Division of Water Supply and Pollution Control
Washington, D.C. 20201

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Other publications in the Industrial Waste Guide Series

- PHS Pub. No. 991: Poultry Process Industry (In Press)
- PHS Pub. No. 952: Fruit Processing Industry
- PHS Pub. No. 756: Potato Chip Industry
- PHS Pub. No. 691: Cane Sugar Industry
- PHS Pub. No. 677: Cotton Textile Industry
- PHS Pub. No. 509: Commercial Laundering Industry
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- PHS Pub. No. 386: Meat Industry
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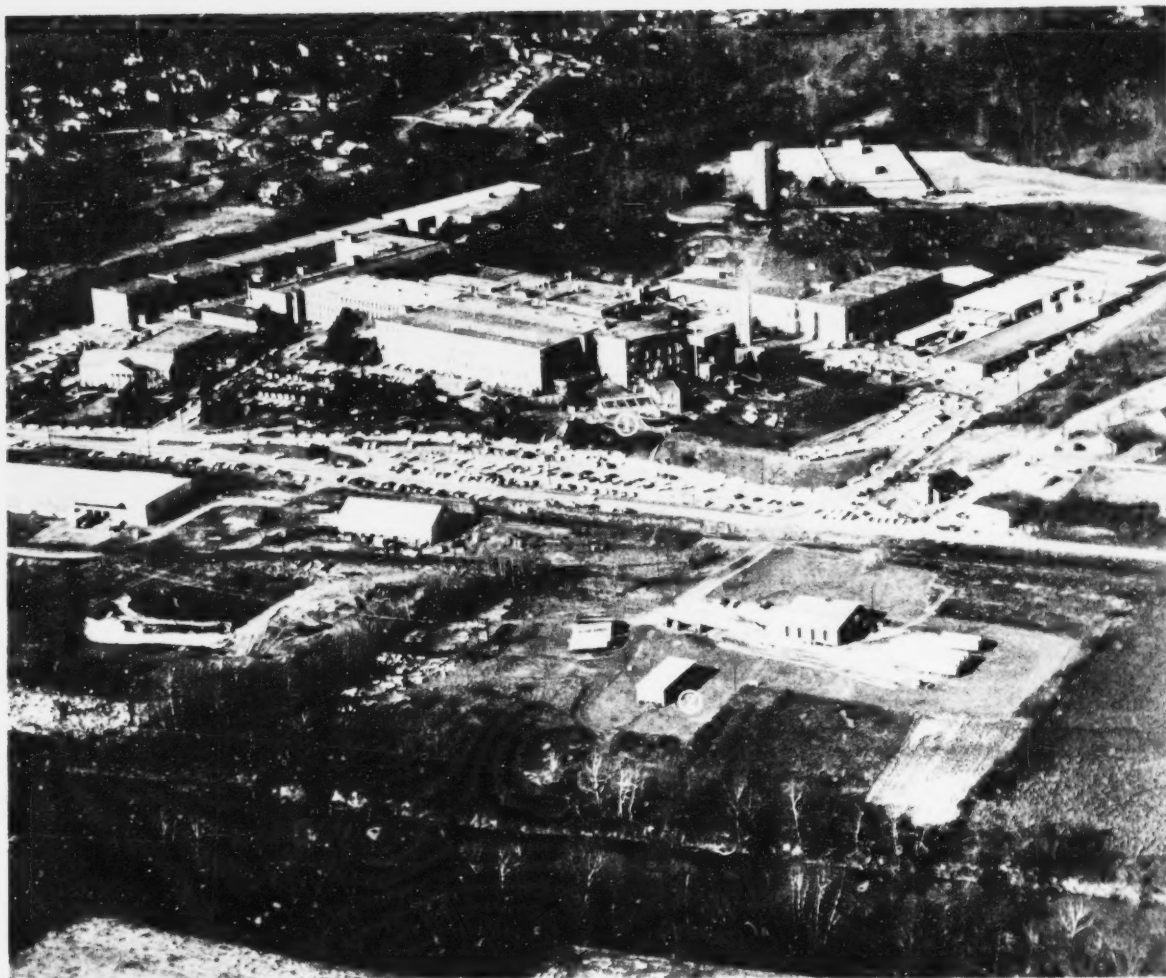
An Industrial Waste Guide to the Synthetic Textiles Industry

Foreword

All industries and municipalities must dispose of their liquid wastes in some way that will not seriously contaminate the receiving streams. This is not only good economics for communities and the Nation as a whole but is rapidly becoming a matter of survival. This guide describes some of the problems involved in the treatment of wastes from the synthetic textile industry. It offers general treating methods to guide those who must determine the particular kind of treatment needed for wastes issuing from the processing of synthetic textile fibers and blends of these with natural fibers.

The National Technical Task Committee on Industrial Wastes (NTTCIW) is composed of representatives from the Nation's leading industries concerned with solving difficult industrial waste problems. The organization's objective is to perform technical tasks pertaining to industrial wastes in cooperation with the Public Health Service and all others concerned with improving the quality of our water resources. To carry out this objective, and as the textile industry representative in NTTCIW, the American Association of Textile Chemists and Colorists, through its Committee on Stream Sanitation, prepared this guide under NTTCIW sponsorship. The author, Mr. Arthur L. Smith, was assisted greatly by Committee Chairman R. Hobart Souther and committee members.

This is the 10th in a series of Industrial Waste Guides prepared by the National Technical Task Committee in cooperation with the Public Health Service.



Synthetic Fiber Processing Plant provided with (1) water filtration and (2) waste treatment system.

Introduction

We hear much of impending water shortage in the United States. There will be no shortage if water is properly used and reused (1), but we must do this increasingly and very soon if there is to be enough water for all. Also, both industry and cities will have to control more carefully the waste loads discharged to streams.

The textile industry has long been a large water user and consequently a large polluter, in terms of both volume and strength of wastes discharged. This booklet presents methods of evaluating the industry's waste load discharge and its effect on the stream and suggests ways to reduce this load in the most economical manner.

General Problem

A textile finishing mill requires from 5 to 15 or more gallons of water per pound of fabric, depending on the complexity of the finishing process. This water must be of high quality because even small amounts of contamination weaken a fabric in a bleaching operation or change the shade of dyed fabrics in an undesirable manner. Since the textile industry as a whole is one of the largest, the importance of a large supply of pure water

is obvious and it is only logical that finishing plants be located along the banks of a stream of good water. (See photograph, p. IV.)

The amount of waste in any textile plant effluent varies from mill to mill depending on the fiber handled and the kind of fabric manufactured. This is particularly true where the same mill may use synthetic fibers of many types and frequently some natural fibers as well.

Description of Process

The various operations performed on the synthetic fibers in converting them into a finished fabric are outlined in figure 1, a flow diagram for a mill of this type. Many of these processes are dry and produce no liquid wastes and so are not described here in detail.

Dyeing

In the synthetic textile industry, dyeing is usually the first wet operation unless the fiber is to be dyed in piece form. In the raw stock dyeing process, the fiber is loaded into a tub or kettle such as that shown in figure 2, although a pressure-type machine may be used for such fibers as polyester. Dyestuffs, depending on the fiber involved, may range from ordinary acid dyes through acetate and basic colors to special types. The liquid waste discharge will vary from about 8 to about 15 times the weight of the fibers dyed.

Blending, Carding, and Spinning

These along with combing, drawing, and slubbing are dry operations and they serve to properly align and twist the fibers to make a satisfactory yarn. They produce no significant wet wastes.

Winding, Warping, and Slashing

Winding also is a dry operation and serves merely to place the yarn in more suitable packages for subsequent operations. At this stage, however, the fibers might be dyed in yarn form as skeins of 1 or more pounds, or on a warp beam weighing several hundred pounds. This is a wet operation yielding about the same liquid wastes as the first dyeing operation.

When preparing yarns for weaving, it is necessary to have all the warp yarns together so as to wind them

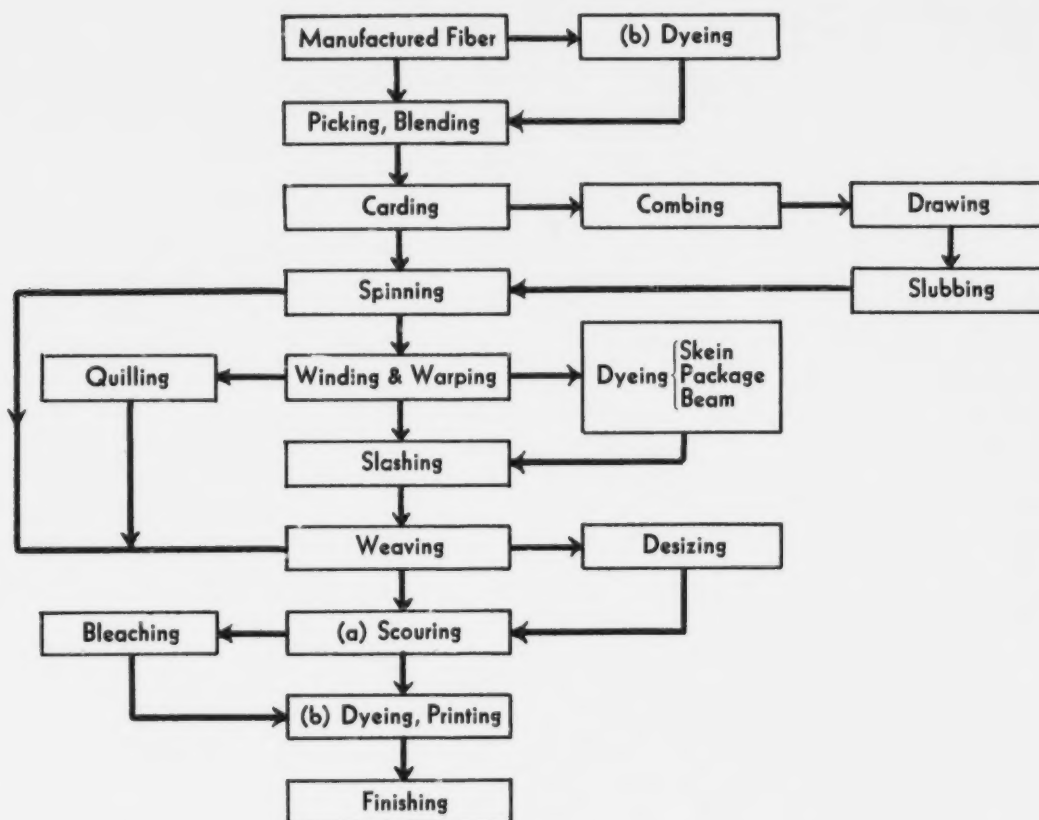


FIGURE 1. Flow sheet for a typical integrated textile mill using synthetic fibers. The letters in this chart refer to operations described in table 1.

onto spools known as warp beams. The beams may be several feet long, 2 to 4 feet in diameter, and contain many hundreds of pounds of yarn. For many yarns, and particularly the fine ones, a coating of protective material is needed to reduce wear during the weaving operation. This coating is applied by slashing; i.e., the yarns from the warp beams are run through a solution of starch, gelatin, or other suitable material, squeezed, dried, and wound onto loom beams. These beams may contain anywhere from a few hundred to several thousand yarns laid side by side. Although slashing is a wet operation, almost no waste issues from it at this point. The bulk of the wastage comes from the finishing operations when the coating is washed off the fibers.

Weaving

The warp beams are taken to the looms where this yarn is crossed with filling yarns to form the desired fabric. This is then inspected and may be heat-set or given other dry finishing as needed.

Dyeing and Finishing

In preparation for the finishing, the fabric may be desized by a treatment with enzyme or acid to decompose the size. Waste from such an operation can contribute heavily to water pollution. Frequently, however, this process is bypassed and it then becomes part of the scouring operation. (See fig. 3.) Bleaching may replace dyeing. Normally some formulation of

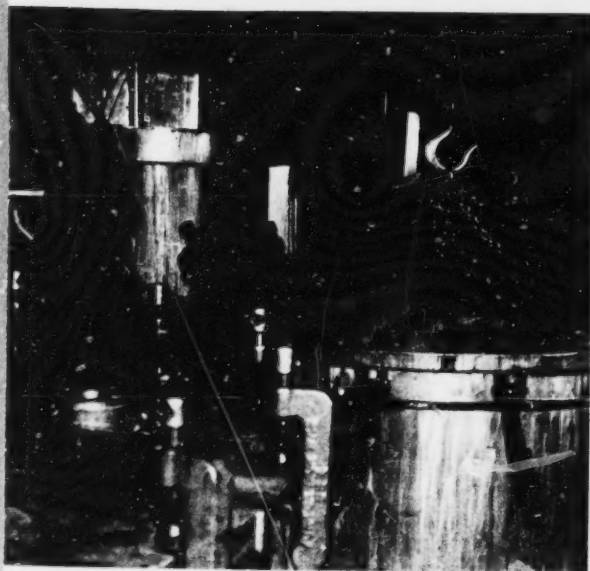


FIGURE 2. Raw stock dyeing machine.

sodium chlorite is used on synthetic fibers. This procedure does not contribute much to oxidizable pollution and, in fact, it may counteract the biological oxygen demand (BOD) of other operations to a limited degree because of the strong oxidizing action of the chlorite and peroxides used.

After this preparation, the fabrics may be dyed in any of a great number of ways. (See fig. 4.) Details will

not be discussed here, but the general types of dyes include:

Vat—This is applied in a reduced state and then oxidized. On cellulosic fibers, these colors have excellent light and wash fastness but are rarely satisfactory on the true synthetic fibers.

Developed—The dye is applied to the cloth, diazotized, and the color formed with a second chemical known as the developer. Again these colors are best on cellulosic fibers.

Naphthol—The naphthol is applied to the fabric, after which the color is formed with a developer. These dyes are best for cellulose, polyamide, and polyacrylic fibers.

Sulfur—The dye is applied in a reduced state and then oxidized to obtain good fastness to light and washing. They are used almost exclusively on cellulose fibers.

Basic—These dyes are used with tannic acid on cellulose fibers or alone on polyacrylics. Specially chosen colors have proved to be among the best for this latter fiber.

Direct—These are applied directly to the cloth and are of very limited use except on cellulose.

Acid—These are applied from neutral or acid bath. They have limited use on polyacrylics but are best on polyamides.

Disperse—While this group has some weakness in wash fastness, it is the most generally useful of all the dyestuff classes on synthetic fibers including acetate but not viscose rayon.

FIGURE 3. Continuous scouring of fabrics woven from synthetic fibers.

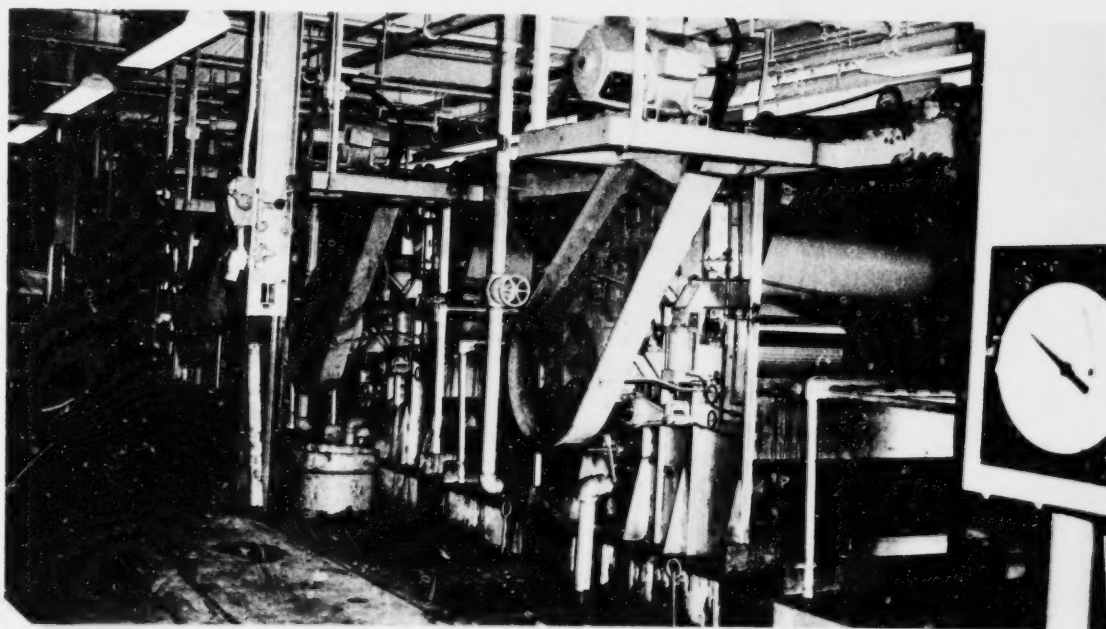




FIGURE 4. Dye kettle for woven synthetic fabrics.

Sources, Characteristics, and Pollution Effects of Process Wastes

The Meaning of "Pollution"

Water is said to be polluted when its character is changed by the addition of materials, or in any other manner, in such a way that the usefulness of the water is reduced.

In their natural state, most bodies of surface water and flowing streams are relatively clear and colorless and contain several parts per million (ppm) of dissolved oxygen which is supplied by absorption from the air and to some extent by plantlife in the water. Dissolved oxygen in the water is as necessary for the existence of fish and many other desirable kinds of aquatic life as is the oxygen in air for the existence of man and land animals. Clarity of the water permits the transmission of light which retards undesirable bacterial growth and generally contributes to a healthy and balanced population of aquatic organisms. Fresh waters in this kind of environment are usually suitable for most uses such as a source of municipal and industrial water

supplies, recreational bathing, fishing, irrigation, etc.

Pollution represents any undesirable departure from the conditions described. It can occur naturally as well as artificially. The most common form of natural pollution occurs when rains wash dirt from uncovered ground and when heavy streamflows stir up the stream bottom. The stream is thus polluted by muddying, which may destroy animal and plantlife on the bottom, reduce fish populations, and render the water less suitable for many beneficial uses. Improper land-use practices of man contribute greatly to this form of pollution. Another source of natural pollution is the leaching of excessive quantities of salts or harmful materials from the formations over and through which the water flows. The alkali waters of the Southwest are examples of this type of pollution.

Manmade pollution results chiefly from the discharge of wastes from cities and industries. Domestic wastes are relatively uniform in composition and in their effect on streams. Methods of treating municipal sewage are

fairly standard. Therefore, wastes from the textile plant's sanitary facilities can usually be discharged to public sewers without special concern to the plant operator.

In contrast, industrial wastes vary widely in character and in their polluting effects so that each is a special waste treatment problem.

Most organic substances undergo a more or less gradual chemical or biological change which takes dissolved oxygen from the water. The extent of oxygen depletion depends on the rate of this oxygen demand in relation to the reaeration characteristics of the stream. If the dissolved oxygen is reduced below certain limits, desirable fish and aquatic life cannot exist. Complete removal of dissolved oxygen from a stream results in a septic condition characterized by obnoxious odors, floating solids, and a generally disagreeable appearance. Suspended organic solids may deposit on the bottom of quiet areas in the stream, concentrating the oxygen demand of these wastes in those areas. Waters containing considerable organic material are generally unsuitable for municipal and industrial water sources and for recreational and some agricultural uses.

The introduction of disease organisms or harmful bacteria into the stream is another form of pollution which is particularly harmful to uses such as drinking water sources, recreation, and bathing. Sewage is the principal cause of this type of pollution.

Excessive concentration of soluble inorganic salts generally renders water unsuitable for industrial and municipal water sources and perhaps even for farm use. Concentrations of sodium and boron salts above certain limits cannot be tolerated in irrigation water. A serious disadvantage of this type of pollution is that soluble inorganic salts are not usually removed by natural stream purification processes and these substances may affect the use of the water far downstream from the point of entry. Acids and alkalies react to form salts and, in addition, have corrosive effects on boats and structures in contact with the water.

A number of substances are toxic to fish and aquatic life. Many of the metals which may be present as salts fall into this category. The acids, alkalies, and numerous members of other classes of compounds may have similar effects. Some substances are also toxic to humans if present in sufficient concentration in water supplies.

Pollution may be in the form of the addition of tastes, odors, and color to the water. Phenol is an example of a pollutant which results in serious taste problems in drinking water supplies. Color in itself is esthetically objectionable, particularly in drinking and recreational waters, and sometimes cannot be removed economically.

A simple but highly important factor is thermal pollution. If a mill discharges a large volume of hot water into a relatively small stream, fish cannot exist for a distance downstream and other abnormalities might develop.

Foam is a particularly unsightly contaminant and presents a serious problem that cannot always be handled satisfactorily.

Suspended, inert matter may also have detrimental effects on the utility of the stream. It makes the water turbid, reduces light penetration, and much of it eventually settles on the bottom. The turbidity increases the cost of treatment required for municipal and industrial uses. Deposits on the bottom may harm bottom-dwelling aquatic life, reduce the carrying capacity of the stream channel, and shorten the useful life of reservoirs. There are instances in which the deposition of industrial wastes has increased the dredging necessary to maintain ship channels.

A textile finishing plant will consume a few thousand to several million gallons of water each day, and most of this is discharged as waste. Such a waste will contain very short fibers of rayon, polyamides, polyester, polyacrylic, or whatever fiber the mill happens to be processing. (See table 1.) In addition, it might carry detergents, soda ash, common salt, Glauber's salt, dye-stuffs, dyestuff carriers, fixing agents, starch, synthetic resins, gelatin, acetic acid, or any combination of such waste products. (See appendix B.) Not all will carry the same degree or even the same kind of pollution. For example, a soap will have a high BOD and some alkalinity, whereas a synthetic detergent might carry neither. Soda ash will carry no BOD, but will have an appreciable alkalinity. Many of these effects are summarized in table 2 and a better understanding might be obtained from a consideration of the various synthetic fibers and their handling (5).

A. Rayon. Although rayon is not truly a synthetic fiber (it is a regenerated cellulosic fiber), it is here considered as such. This fiber is similar in many ways

Table 1. Data on bath characteristics for different operations and different fibers. These figures are not exact but merely averages of data for 1 mill. The letters refer to the processes of fig. 1

Fibers and operations	Biological oxygen demand			pH	Solids	
	ppm	lbs./1,000 lbs. fabric	Percent owf		Suspended (Percent owf)	Dissolved (Percent owf)
Acrylic:						
(a) Scouring.....	350	5.2	0.52	8.8	0.34	1.56
(b) Dyeing, basic.....	208	3.1	.31	8.3	.05	.60
(b) Softener.....	13	.2	.02	7.4	.06	.14
(b) Dyeing, acid.....	610	8.5	.85	4.2	.16	.92
Rayon:						
(a) Boiloff.....	240	2.0	.20	3.9	.15	3.22
(b) Dye.....	50	.7	.07	7.1	.27	16.0
Rayon-nylon: ¹						
(a) Scouring.....	585	8.7	.87	8.2	7.40	30.60
(b) Dyeing.....	123	1.8	.18	3.5	.14	8.90
(b) Fixing.....	112	1.7	.17	7.0	1.69	8.33
Nylon:						
(a) Scouring.....	2,260	34.0	3.40			
(b) Dyeing.....	675	10.0	1.00	7.6	.01	2.66
Acetate: Overall.....	665	50.0	5.00			

¹ 50 percent blend of each.

Table 2. A listing of some polluting factors in the discharge from textile mills using synthetic fibers

Polluting agent	Effect
1. Dyestuffs	Discoloration; BOD
2. Alkali	Alkalinity, soluble residue
Soda ash	
Sodium hydroxide	
Sodium phosphate	
Sodium silicate	
3. Hydrogen peroxide.....	Oxidizing (negative BOD)
4. Sodium hypochlorite.....	Oxidizing, perhaps alkalinity, soluble residue
5. Sodium chlorite.....	Oxidizing, perhaps acidity, toxicity, soluble residue
6. Sodium or potassium dichromate.	Oxidizing, toxicity, soluble residue
7. Stripping agents.....	BOD, sometimes toxicity, soluble residue
8. Dye carriers.....	BOD, frequently toxicity, soluble residue
9. Gelatin	BOD
10. Synthetic sizes.....	Usually acidity, soluble residue
11. Finishing resin.....	BOD, soluble residue, sometimes toxicity

to cotton, yet requires slightly different handling methods. Fabric woven from rayon fiber normally contains a soluble (or emulsifiable) spinning oil (2 percent on weight of fiber designated) and a synthetic detergent (3 percent owf ¹) might be used for scouring. Any antistatic in the oil accounts for an estimated 50–60 percent of the BOD, the soluble oil an estimated 30–40 percent, and the detergent up to 20 percent (although some detergents have none). The combined waste from scouring and a salt bath will approximate 5.7 percent BOD ² (owf) and 8–24 percent (owf) salt; about 5 gallons of water are used per pound of fabric. Additional finishing treatments will, of course, yield additional waste products.

B. Acetate. Acetate rayon (both secondary and tertiary) is an acetylated cellulose and differs extensively from other cellulose. Its swelling is appreciably less in water and this affects its physical and chemical prop-

¹ owf—on the weight of the fiber.

² E.g., 1 percent BOD means 1 pound of BOD per 100 pounds of fiber.

erties. For example, dyeing with acid, direct, or vat colors is very difficult. The preparation of this fiber for dyeing follows about the same procedure as that used for rayon. The waste liquors will frequently contain a sulfonated oil (2 percent owf), detergent (1 percent owf), aliphatic ester (2 percent owf), and softener (2 percent owf). Such a procedure will generally yield 5 percent BOD (owf), with 9 gallons of water being used per pound of fabric. A water-repellent finish might add about another 3.8 percent BOD (owf).

Disperse dyeing of this fiber can lead to confusing interpretation to the waste plant operation. For example, assistants such as acetone or alcohol are sometimes used and these produce a very high immediate BOD that must be given special attention in any waste treatment plant.

C. Polyamides. This is the generic name for any long-chain polymeric amide which has a recurring amide group as an integral part of the main polymer chain and is the first of the truly synthetic fibers to be considered here. The most common is nylon 6-6 so called because it is made from hexamethylene diamine and adipic acid, both of which are compounds of six carbon atoms in a straight chain. Other types are available (nylon 6, nylon 11, etc.) but, although they differ slightly in their chemical and physical characteristics, they are the same as far as this discussion is concerned.

Polyamides differ from the previous fibers in that about 1 percent of the fiber dissolves during a scouring operation. Although this apparently does not affect the strength, it will add a small BOD to the waste liquors.

Polyamide processing may follow the procedure of scour, dye, and finish where the last term can include water-repellent, oil-repellent, or resin finishing, as well as latex backing³ or other finishing. The scouring bath yields about 3.4 percent BOD (owf) and the dye waste about 0.9 percent BOD (owf). A water-repellent finish will add 1-2 percent BOD (owf), and other fin-

³ This can be a very serious problem. In large mills there is usually sufficient water running in the sewers at all times to dilute and carry away the emulsion. In small mills, a particular sewer branch might be dry at times except for the polymer emulsion that is dumped into it. Under the right conditions this can coat the sewer walls and collect in any open joints in the line and has been known to completely clog a small sewer line.

ishes will add the same BOD as they would on other fibers receiving the same finish. Normally, about 15 gallons of water is used per pound of fabric.

D. Acrylic. This fiber appears under many trade names but consists of polymers containing a preponderance of acrylic units, particularly acrylonitrile, in the polymer chain.⁴

As originally produced, the acrylics could be dyed in light shades only with normal dyes and dyeing procedures. This led to high temperature dyeing techniques or, more frequently, carrier techniques using ordinary dyeing temperature but auxiliary chemicals such as copper with hydroxyammonium sulfate, glyoxal, phenols (m-cresol, p-phenyl phenol, etc.) and aromatic amines (aniline, etc.). The use of these compounds introduces a source of toxicity which may or may not interfere with the operation of a waste disposal plant, depending on the amounts used.

A procedure that might be used on this fiber would be scour, dye, and finish. The scouring might yield 6.6 percent BOD (owf) and the dyeing as much as 5.5 percent BOD (owf), and might contain copper or hydroxyammonium sulfate. Because copper frequently interferes with BOD determinations, the true BOD discharge is believed to be somewhat higher than that presented.

Copper and phenol amplify a problem in textile wastes that has been very minor in the past. Phenol in relatively low concentrations can be handled in waste treatment plants. It is reported to cause odors and tastes in drinking water and fish flesh at very low concentrations (2).

Copper is toxic to fish in very low concentration (0.8 ppm), but can sometimes be removed (3). It is also extremely toxic to biological treating systems and its presence in any measurable amounts (1 ppm or more) must be avoided. Chromium (VI) is also toxic but as much as 50 ppm (7) can be tolerated provided the concentration is reasonably uniform with relation to time. Under these conditions, the critical item is not the treatment plant but the stream. A small part of this chromium will be reduced to trivalent chromium

⁴ There is also a mod-acrylic fiber consisting of an acrylic and another unit coupled. While this group has appreciably different physical and chemical properties, it is included with the acrylics for the purpose of waste discussion.

and will deposit in the plant sludge, but much of the chromium at these high concentrations will pass through the plant and act as a pollutant in the stream. This emphasizes another point, namely, that certain toxic materials might not interfere with the operation of a disposal plant but still be deleterious to life in a stream and this is even more important.

Still another problem of this type is being introduced by the industry itself and that is the use of bacteriocidal or bacteriostatic materials for finishing cloth. These will be in the waste in very small quantities, but some are extremely powerful and could interfere with the operation of a biological process. Because of the great variation among products used, the importance of this effect cannot be predicted but its potentialities must be considered.

E. Polyester. These are usually manufactured by the esterification of ethylene glycol and terephthalic acid and similar compounds. They may be dyed at usual temperatures with carriers (6-40 percent owf phenylphenol, phenylmethylcarbinol, salicylic acid, benzoic acid, etc.) or under pressure without carriers.

One procedure for finishing polyesters might be scour, rinse, dye, scour, rinse, and apply any special

finish desired. In the absence of direct analyses, it is estimated from values for individual chemicals that the BOD from scouring might be 1.6 percent (owf) and from the dyebath between 18 and 81 percent, depending on the carriers used. These are extremely high values for a textile operation and all possible methods should be used here to reduce the BOD load in processing, pretreat the waste liquors, or both.

F. Polyolefin. These are polymers of ethylene or propylene and are extremely stable chemically. They are so new that little can be said about their wastes at this time. It is probable, however, that general methods for polyester will also apply to the polyolefins.

G. Summary. Nearly all the BOD resulting from these fibers is from process chemicals, since the fibers themselves contain almost no impurities such as those found in natural fibers. The average contribution to BOD is about 1.5 percent owf, but this might go as high as 80 percent in special instances. With the large quantities of fibers used, it is understandable that some method of reducing this contamination must be exercised if the streams are to be kept in reasonable condition.

Survey Methods

The purpose of this publication is to suggest methods of reducing stream pollution either by in-plant process changes, by treatment of waste liquors, or both. At the same time, any treatment that might be needed must be as low cost as possible and it is useless to treat waste liquors without first knowing what is in them so that some estimate can be made of the effect of treating. Furthermore, a study should be conducted on the stream to determine how much treatment is needed. For example, the use of a stream at any particular place is usually specified by the State, hereinafter known as the regulatory agency. If the stream is to be for fish other than game fish, a certain level of purity will be required. If it is for game fish, a higher level is necessary, and if for bathing or domestic water supplies, still

higher levels. It is then left to the manufacturer to treat his wastes to meet these requirements.

BOD is not the only pollutant, but if it be assumed to be the most important, a waste survey should include two phases: (1) a survey of the condition of the stream, and (2) an in-plant survey of each individual process. If a plant is relatively isolated on a stream, the stream survey is not complicated by wastes from other sources. Under these conditions, the most common method of survey consists of measuring the dissolved oxygen at a series of points downstream to determine whether its lowest point is high enough to meet the requirements of that stream (BOD should be measured at the same time.) Such measurements should be made under different conditions of flow and particularly in time of

drought and warm weather. One of the most important steps in this procedure is to obtain values at a time of no discharge—e.g., on a holiday. With this information and a knowledge of the low flow, a good estimate can be made of the degree of treatment needed.

If a mill is located on a heavily populated stream, the approach outlined is difficult and often impossible or meaningless because of the confusion resulting from the discharge of other establishments. Under these conditions, the discharge load must be determined from in-plant or effluent measurements. In fact, this should be done under any circumstances because (1) it serves as a check on the stream measurements, and (2) it points to possible savings in chemicals within the plant.

One way and perhaps the easiest way to do this is to measure the BOD (4), solids, pH, and any other factors that might be necessary on each wet operation. (If sanitary waste is involved, this must be estimated separately by measurement or a general calculation.) For example, one small dyehouse operates six kettles to scour and dye four different fibers; namely, cotton, wool, rayon, and polyacrylics. Each fiber is scoured as one operation and an analysis on that bath might be something like that shown in table 3. Enough determinations should be made to obtain a reasonable average—never less than three baths. This analysis must be made for scouring, dyeing, softening, bleaching, or any other operation on each kind of fiber or fiber blend. The results can be expressed as pounds of pollutant per machine or it can be put on the basis of the weight of cloth handled. In the example given

Table 3. Analytical data on a scouring bath for an Acrilan fabric

pH.....	8.8.
BOD (ppm).....	351.
Total solids (ppm).....	1,286.
Total volatile solids (ppm).....	924.
Total suspended solids (ppm).....	231.
Total volatile suspended solids (ppm).....	231.
Total fixed suspended solids (ppm).....	0.
Total dissolved solids (ppm).....	1,056.
Total volatile dissolved solids (ppm).....	693.
Total fixed dissolved solids (ppm).....	363.
Alkalinity (ppm).....	131.
Dominant wavelength.....	574.
Purity, percent.....	17.
Hue.....	Yellow.
Luminance, percent.....	18.1.

in table 4, it has been based on the machine. Note in this example that the number of loads of each fiber handled is listed for 1 day (24 hours). The load from each operation is calculated and all loads summed.

It is usually possible to get the total water used in a plant from a watermeter, as was done in the example given. Frequently such meters are not available on continuous operations and estimates must be made by such methods as weirs, Parshall flumes, and flow timing. The concentration must also be measured by standard methods (4). It is then straightforward arithmetic to calculate the contamination discharged per day either as total pounds or as concentration in the liquid.

Toxic materials such as copper, chrome, sulfide, phenols, etc., might be present and these must also be

Table 4. The calculated loading of effluent liquors

Water consumption: 216,490 gallons total			
19 sets of rayon scoured, dyed, and fixed			
9 sets of rayon scoured only			
6 sets of acrylics scoured, dyed, and softened			
Each bath contained 1,200 gallons of water			
	pH	BOD (lbs.)	Total suspended solids (lbs.)
Rayon:			
Tint rinse.....	6.9	70	44
Scour.....	7.7	77	55
Bleach.....	8.4	4	17
Antichlor.....	5.0		14
Dye.....	6.5	16	48
Soften.....	6.8	21	22
Rayon:			
Tint rinse.....	6.9	33	21
Scour.....	7.7	36	26
Bleach.....	8.4	2	7
Antichlor.....	5.0		6
Acrylic:			
Scour.....	8.8	21	14
Dye.....	8.3	12	2
Soften.....	7.4	1	2
Total.....		293	275

Calculated analysis of effluent

pH.....	about 7.04
BOD.....	167 ppm
Suspended solids.....	152 ppm

identified and measured. In the example given, these were not present.

In a heavily populated section, this information will suffice. Those concerned [the regulatory agency] with

the solution of the problem could combine these data with corresponding data from other sources to calculate the effect on the stream and decide what degree of treatment is necessary.

Remedial Methods

While this publication discusses the need for waste treatment for textile plants, the initial step should be the reduction of wastes at their source. It is always possible that means can be found for reducing the waste discharge and such measures frequently lead to economies. Questions to be answered include (5):

- (1) Would closer process control reduce pollution?
- (2) Could better housekeeping methods be found?
- (3) Can a process having a low pollution load be substituted for one having a high load, or, for example, can some chemicals with low BOD be substituted for others with high BOD?
- (4) Does the waste have valuable components that can be recovered?

On relatively unpolluted streams, it is always possible that sufficient improvement can be made in the mill to reduce the size of the disposal plant.

Good housekeeping as such cannot be expected to yield great improvements in the product, but by reducing the possibility of stains, rust, and dirt getting on cloth, less rigorous washing or rinsing might be possible which would result in a lower waste discharge. Further, if dyeing is done carefully and cloth handled properly beyond this point, reprocessing can be reduced and with it the amount of waste discharged. This carries an additional bonus of a more economical process, greater output from the same pro-

duction facilities, or both. These procedures should reduce the waste load by 5 percent or more.

Closer process control will also yield double dividends. Frequently, a mill has established scouring and finishing formulas to take care of the most extreme conditions with a safety factor of 10-60 percent. Since these extreme conditions exist perhaps 5 percent of the time, large excesses of chemicals are being used. Eliminating the rigorous conditions at times when they are not needed will result in lower waste concentrations and lead to less pollution and lower chemical costs.

This reasoning can be applied in other ways. Frequently trouble is experienced in dyeing fabrics. In the urgency of correcting the problem, a new chemical is sometimes added to the bath without careful study to see if it is effective. After the dyeing problem has disappeared, the new chemical usually is retained as a basis of "insurance." Obviously, if careful tests show the added product to be necessary, it must be retained. On the other hand, if it is not helpful in the dyeing, then its use should be discontinued, since it is not only adding to the waste load but also to the expense of dyeing.

Warp sizing is another example. A heavy coating is necessary in warps having a great number of tightly twisted yarns, but need not be used on yarns of lower twist or warp of more open construction. Again, this provides a double saving. The reduction in BOD from these changes might be as much as 30 percent which, coupled with reduction from better housekeeping, would reduce the size of a treatment plant.

Changing chemicals is another very profitable approach. This procedure has greatly reduced the waste discharge in some cotton mills (5). Similar results can be achieved in synthetic textile mills. Changes

such as the following might be instituted when feasible:

- (1) Replace soap (140-155 percent BOD⁵) or high BOD detergents with low BOD detergents. This is not always possible since the low BOD detergents are not easily degradable and might lead to a foam nuisance on the stream.
- (2) Use low BOD auxiliary chemicals in dyeing (dyestuffs themselves can rarely be considered because specific dyes are needed for specific shades regardless of BOD).
- (3) Use steam ranges for oxidizing dyes instead of dichromate-acetic acid baths.
- (4) Use pressure dyeing instead of carriers.
- (5) Replace acetic acid with ammonium sulfate or chloride, phosphoric acid, or other inorganic materials.

Thus the carding and spinning oils once used (about 100 percent BOD⁵) can be replaced by mineral oil and emulsifiers (about 20 percent BOD⁵ or less) to achieve an appreciable savings. This procedure can be broadened by using the data included in appendix B.

Recovery of chemicals is also a possible approach. The spinning oil used on fibers can be recovered by dry cleaning a fabric instead of scouring it. Under these conditions, no detergent, solvent or grease (oil) from the cleaning operation goes into the waste so that a very large savings in BOD can be achieved. The oil recovered can be sold or, in a few instances, reused.

Further chemical recovery will depend largely on the economics of the mill and the ingenuity of the operators. But it can be seen that very great reductions in BOD can be accomplished by the methods discussed. Caution must be exercised, however, to be sure that these changes do not affect the operation of any existing disposal plant or lead to new pollution in the stream.

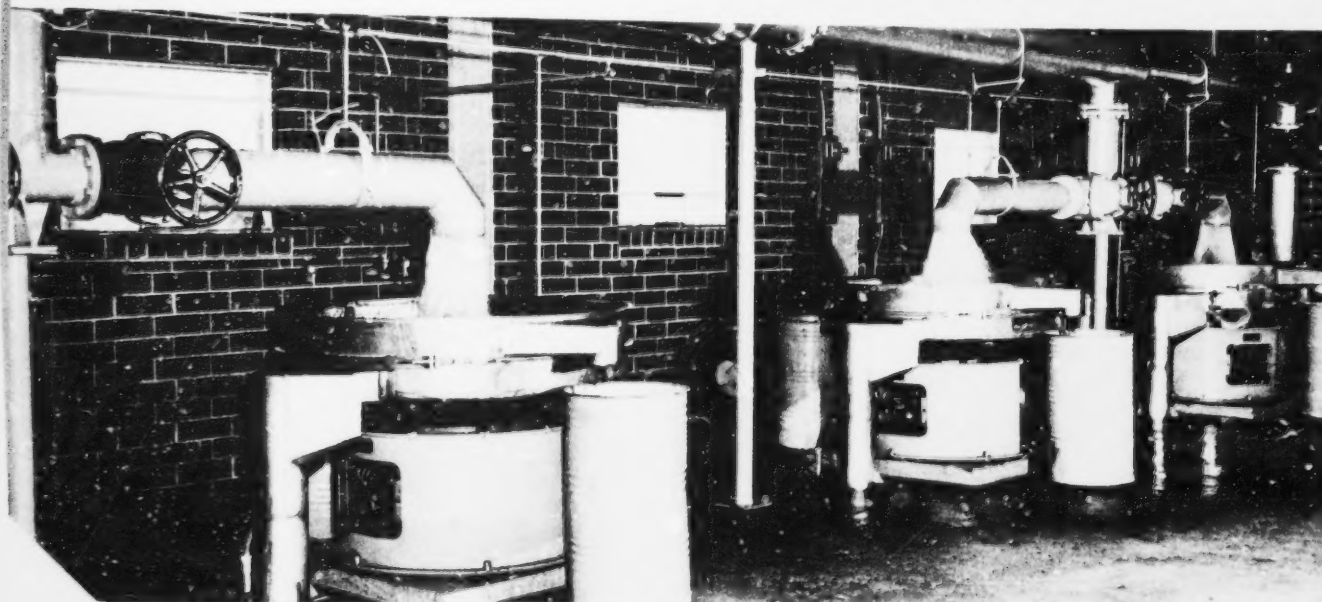
⁵ See appendix B.

Treatment Methods

When all these methods have failed to meet the requirements for any particular mill, steps must be taken to treat the waste by one or more methods. This can be a simple method such as screening or settling or it can

be a very complex method involving these plus elaborate aeration and separate treatment for toxic materials. Table 5, while not complete, does cover several commonly available methods.

FIGURE 5. Removal of floating solids from synthetic wastes by screening—an installation of vibrating fine screens.



A. Solids separation. This may be accomplished by at least three methods, of which screening is common.

1. A fixed screen such as a series of bars which are cleaned at intervals by hand might be used. A mechanical scraper can be added or a cylindrical, or a chain-type, screen can be used which is sturdy and self-cleaning. Vibrating screens can be used to advantage. (See fig. 5.) They must be carefully matched to the needs, since they vary from an inefficient but extremely sturdy type to highly efficient circular screens, some of which require considerable maintenance. It should be noted that "highly efficient" in terms of screening might mean removal of only 10 percent of filterable solids.

2. Physical-chemical methods offer another means of solids removal and these are sometimes of greatest value to the small plant. Sand beds, either simple or back washed, may be used for more complete removal of solids. These are often overlooked in the current search for more efficient methods. Some small mills are making very good use of ordinary sand filter beds such as shown in figure 6. The upkeep is nominal and they prevent the formation of sludge banks in any stream receiving their discharge. Settling tanks or lagoons may be used to remove the large suspended solids.

3. Treatment by very rapid aeration of incoming waste, usually with the addition of small amounts of sludge from another part of the process, is used to increase particle size and aid in subsequent settling. The retention time is usually too short to permit any measurable degree of oxidation.

B. Biological treatment.

1. *Waste preparation.* A certain amount of preparation is necessary for this step. Perhaps the pH of the waste must be adjusted to some particular value. This can be done through the addition of acid (such as sulfuric) or alkali (such as lime). If the acidity or alkalinity of the effluent varies from time to time, a simple blending of the wastes in a small holding tank may suffice to suitably adjust the pH. Perhaps the flow varies from time to time, but the treating system will only accept a limited loading. Proper ponding will serve to equalize the loading. An adjustment in temperature might be required. Ponding will again serve

for a slight degree of cooling, but extensive cooling will require a cooling system (such as a heat exchanger) or extensive heating will require some source of heat (such as steam).

The removal of toxic materials is extremely important for a biological system. Metallic ions such as copper or chromium must be removed or reduced to acceptable values. Nonmetallic ions such as sulfide and cyanide are equally important and are usually handled chemically. In some situations, color can be highly important. If this is simple iron rust, it is relatively easy; if a dyestuff, it can be very difficult and sometimes economically impractical to remove.

As mentioned before, some systems do not settle well without preaeration. This operation might also be necessary to avoid septic conditions where preliminary ponding is necessary.

If an ordinary lagoon is used, odor control can become a serious problem. Conceivably, satisfactory control is not always possible, but certain methods are sometimes successful. Odor resulting from simple volatile fatty acids can be controlled by the use of alkali (pH 8 or slightly higher). Usually control is not this simple and other odors might be absorbed with activated

FIGURE 6. Sand filter waste treatment system for a small textile plant.



charcoal. The amount used must be determined for each individual plant. One of the newer and more economical methods is odor neutralization, a process of spraying with a chemical that just counteracts the undesirable odor and is not noticeable to the sense of smell. Additional but sometimes expensive methods include oxidation with chlorine, sodium nitrate, oxygen, ozone, or other strong oxidizing agents.

Many times a particular waste is lacking in some essential nutrient such as nitrogen or phosphorus. As a last preparation step, this can be added as ammonia and phosphoric acid, or ammonium phosphate, depending on specific requirements.

2. *Waste treatment.* This further step can constitute mere ponding of the liquors in a deep container for the desired length of time (anaerobic) or impounding in shallow basins called oxidation ponds (aerobic) or treating by a highly elaborate aeration system (6) giving almost any desired degree of pollution reduction (table 5).

Perhaps the easiest way to understand the application of biological treatment would be to choose a hypothetical example. Figure 7 shows a schematic plant layout that includes most common treating methods. Obviously, not all these steps would be used in any particular installation, but if a high degree of treatment were necessary, many of them might be used in combination. To follow this through, suppose a mill's (9) waste contained small amounts (less than 0.3 ppm) of copper or chrome but no other toxic elements, plus considerable short fibers, had a medium (about 200 ppm) BOD and slight discoloration. Suppose, also, it was necessary to remove only 50 percent of the BOD. First, the metals are not present in sufficient concentration to interfere with biological treatment. The lint can be partially removed by screening or lagooning. The latter is probably more effective, but it also removes some organic materials that might lead to objectionable odors. Screening might be chosen and steps A and B of figure 7 are eliminated. A waste of this kind likely would not require preaeration, although studies would have to be conducted to confirm this. If not, step D is unnecessary. Oxidation ponds could be used for this waste, but they require large land areas and are less efficient under winter conditions than aeration methods. (See figs. 8 and 9.)

Table 5. A summary of waste disposal methods starting with the simplest. The list is not complete but covers a wide range of methods. For any specific problem, 2 or more methods might be combined to achieve the desired results.

- I. Solids separation
 - A. Mechanical
 1. Screens
 - a. Manual (bar)
 - b. Powered
 - i. Cylindrical both rough and finish
 - ii. Vibrating
 2. Centrifugal
 - a. Basket
 - b. Disk
 - B. Physical-chemical
 1. Sand beds
 - a. Simple
 - b. Back wash
 2. Settling
 3. Flotation
 - C. Biological
 1. Activated sludge (used as a preconditioner)
- II. Secondary treatment
 - A. Preparation
 1. pH adjustment
 - a. Chemical equalization
 - b. Time equalization
 2. Control of flow
 3. Temperature control
 4. Toxicity removal
 - a. Metallic ions (copper, chrome, etc.)
 - b. Nonmetallic ion (cyanide, sulfide, etc.)
 - c. Color
 5. Preaeration
 6. Odor control
 - a. Alkalinity (lime, etc.)
 - b. Absorption (activated charcoal)
 - c. Oxidation
 - i. Chlorine
 - ii. Sodium nitrate
 - iii. Ozone
 - d. Odor neutralize
 7. Nutrient addition
 - B. Treatment
 1. Lagoon
 2. Aerated lagoon
 3. Oxidation pond
 4. Activated sludge
 - a. Trickling filter
 - b. Supra-activation
 - c. Modified aeration
 - d. Activated aeration
 - e. Biosorption (contact stabilization)
 - f. Kraus
 - g. Rapid bloc
 - h. Step aeration
 - j. Conventional activated sludge

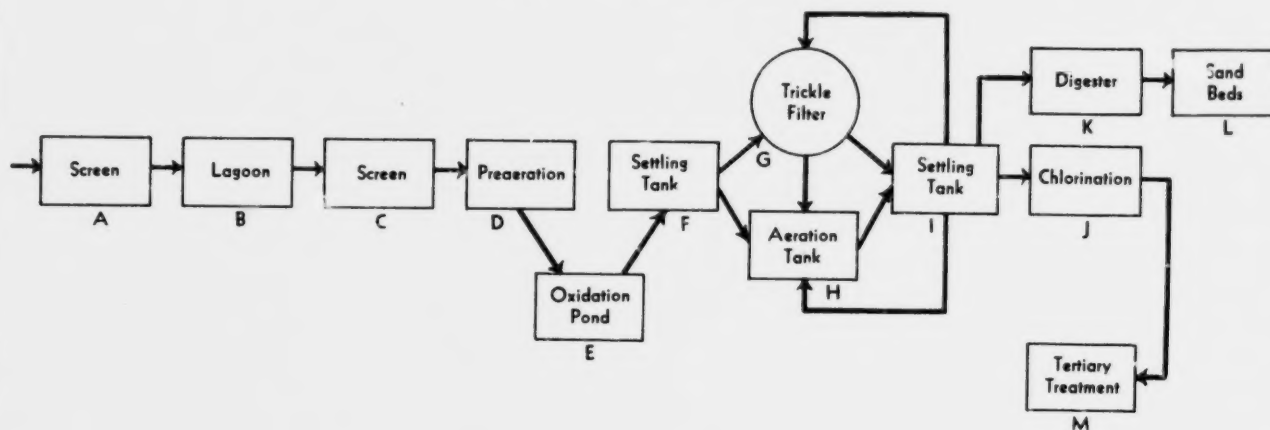
In this example the land area was not available for ponds, so steps E and F were eliminated. A trickling filter could be used for the next step, but this is an expensive item in terms of initial cost and may be inefficient for some industrial wastes. Furthermore, with only screens ahead of it, there is danger of clogging. In fact, one experiment (9) is known in which a standard stone bed showed clogging tendencies in 3 weeks' time. This problem can be minimized by the use of open cellular or similar-type construction, but the BOD of this hypothetical waste is only 200 ppm and these units work best at higher loadings. In view of this and other considerations, step G was discarded in favor of step H of figure 7, the activated sludge process. However, there are instances where a trickling filter is used as a roughing treatment and activated sludge treatment is used as a finishing process, particularly where very complete treatment is necessary.

Based on table 6, the supra-activation method might be chosen since it requires no primary treatment, removes about half the BOD as is required, and is a very

high rate treatment, i.e., a relatively small installation is required. Thus, steps H and I were used (fig. 7). Since this waste contains practically no pathogenic organisms, steps J and M were not needed.

The last two steps to be considered would be a digester (K) and sand beds (L) for processing the solids removed. There are some alternatives. If the plant is large enough, i.e., produces enough sludge, the digester can be replaced by a wet combustion. Under these circumstances, the sand beds are not necessary. An aerated digester can be used. This is similar to an aeration tank but with appreciably lower airflow and higher solids concentration. One pilot plant (9) has operated for more than a year without the need of sludge removal. Although it cannot be said at this time that the aerated digester will eliminate the need of sand beds, it will greatly reduce the size of any beds required. In addition, indications are that operation is much more trouble free than that of the usual anaerobic digester.

FIGURE 7. Hypothetical treatment process.



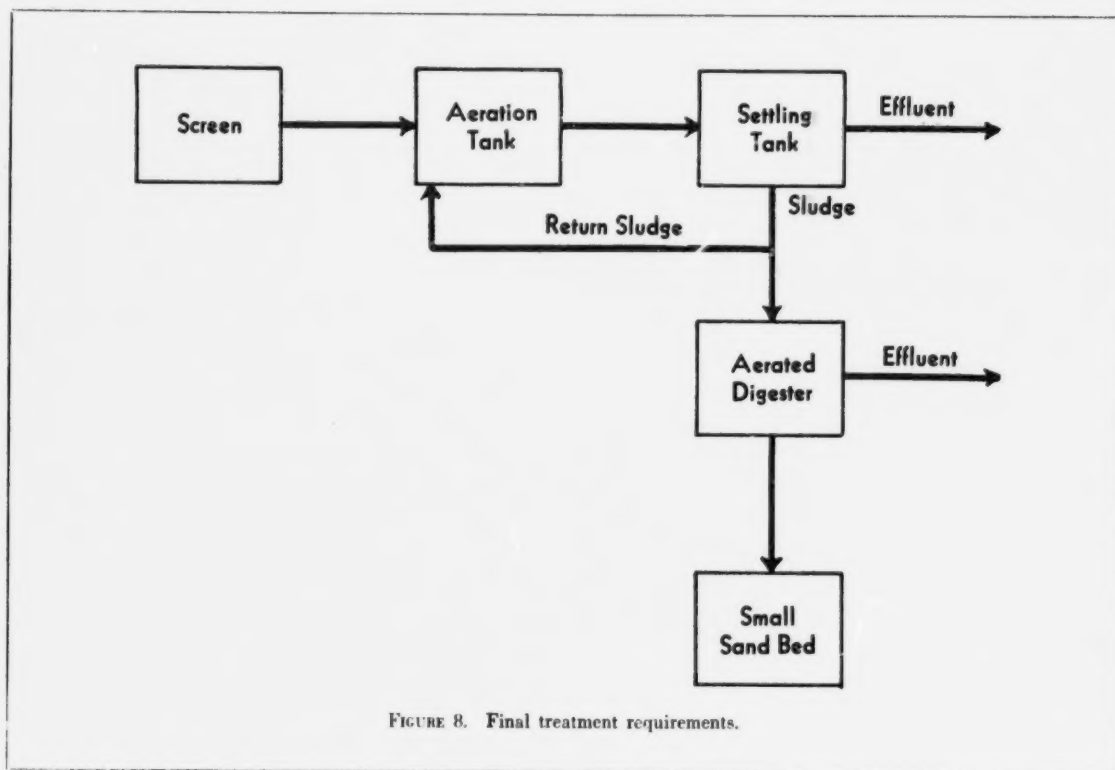


Table 6. Design practice of high-rate processes for sewage ¹

Process	Degree of treatment (percent BOD removal)	Primary required	BOD design load ²		cu ft air/lb BOD removed
			lbs/1000 cu ft aeration tank	lbs/lb mixed liquor suspended solids	
Supra-activation.....	55-65	No.....	400	3.3-5.0.....	400-350.
Modified aeration.....	60-75	No.....	100	3.3-5.0.....	600-400.
Activated aeration.....	80-85	Yes.....	50+	0.33 step aeration section.	0.36 cu ft/gal.
Biosorption (contact stabilization).....	85-90	Optional.....	70	0.25-0.50.....	750.
Kraus.....	89	Yes.....	100	0.5-0.7.....	800.
Rapid bloc.....	90+	Optional.....	125-180	0.66-0.97.....	500.
Step aeration.....	92+	Yes.....	³ 50-150	0.33.....	700-500.
Conventional activated sludge.....	95+	Yes.....	35	0.33.....	1000-700.

¹ Taken from Klegerman "High Rate Activated Sludge Treatment Processes," presented at 11th Southern Municipal and Industrial Waste Conference, Chapel Hill, N.C., Apr. 19-20, 1962.

² European practice.

³ These data refer to sewage but were included to show the variations possible with aeration techniques. Textile wastes will sometimes require different loadings or different aeration rates.



FIGURE 9. Bioaeration system for treatment of textile wastes.

Summary

In determining disposal methods for wastes from the manufacture of synthetic fiber textiles, the first approach should always be a study of in-plant methods and chemicals. Frequently, better methods will reduce the amount of waste and, consequently, any waste discharge into a stream. More rigid processing controls may lead to less reprocessing and consequently lower waste loadings. High BOD chemicals might be replaced with chemicals having a lower BOD where this does not lead to other stream problems. It is entirely possible in special instances that this is all that is necessary; the receiving stream might then meet the requirements of the regulatory agency.

Although BOD is emphasized here, it should be remembered at all times that this is not the only objectionable factor in waste. For example, in replacing soap with a synthetic detergent, a very stable and therefore highly objectionable foam might develop in the stream, particularly in the presence of proteins (7). Exces-

sively hot wastes should be sent through a heat exchanger before being discharged into a stream. Toxic materials must be watched; some will not be removed by, nor interfere with, a treatment plant but will go through it into the receiving stream.

If these measures prove insufficient, then further steps must be taken and the first is to determine how much treatment is necessary. This can usually be done through two basic studies. The stream should be analyzed to determine its solids content, pH, DO, BOD, and any other pertinent factors. The plant wastes should be studied similarly either at their source or points of discharge. From these data, the necessary degree of treatment can be estimated.

Many plants will need some degree of treatment and almost anything desired can be obtained. Several methods are presented, ranging from lagoons to highly complex systems providing the maximum possible treatment.

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Appendices

Appendix A is an abbreviated bibliography of articles on waste disposal over the past 12 years that apply particularly to plants using synthetic fibers. For a more complete listing, see *American Dyestuff Reporter* 44, No. 6, P168-190, March 14, 1955.

A second appendix presents an abbreviated list of chemicals and their BOD. This suggests some chemicals of low BOD that might be used to replace those of high BOD. Additional information is given in the *American Dyestuff Reporter*.

Appendix A

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Appendix B

An abbreviated list of the 5-day BOD of Textile Chemicals. These values are based on the weight of chemicals as received, i.e., if a chemical shows a BOD of 140 percent, then 1 pound will yield 1.4 pounds of BOD. The exception to this is reference 5 where the BOD is based on the dry weight of chemical.

Name	Ref.	Composition: use	BOD percent
Acetic Acid, 56%.....	(2)	CH ₃ COOH; dyeing, scouring.....	33, 36.
Acetone.....	(2)	CH ₃ COCH ₃ ; solvent.....	122*.
Aerotex Resin M-3.....	(2)	Melamine-formaldehyde; finishing.....	23.
Aerotex Syrup 250 Conc.....	(2)	Urea-formaldehyde condensate; durable finishes.....	5.
Aheovel G.....	(2)	Fatty carbamide; cation-active sustantive softening agent.....	2.
Alkamine C.....	(5)	Fatty amide condensate.....	45.
Avcosol 20.....	(1)	Waxy sorvital ester; sizes, spinning and carding oil.....	42.
Avitex R.....	(2)	High alkylamine; special finishing agent.....	5.
B-2 Gum.....	(2)	Starch dextrans; printing ink, size.....	61.
Brytex Gum No. 745.....	(2)	Starch; printing ink, sizes.....	61.
Carbowax 200.....	(5)	Polyethylene glycol.....	2.
Cetosol SF.....	(2)	Synthetic resin; finishing.....	24.
C-Prosan.....	(6)	Synthetic wax.....	129.
Duponol C.....	(2)	Lauryl sulfate; detergent and wetting agent.....	125.
Duponol RA.....	(7)	Surface active agent.....	13.
Dyes			
Alizarine Cyanine Green GHN Conc. CF.....	(2)	Acid dye.....	Near 0**.
Calcogene Black GXCF Conc.....	(2)	Sulfur dye.....	10.
Celliton Fast Blue AF 100%.....	(2)	Acetate color.....	3.
Erie Brilliant Black S 150%.....	(2)	Direct dye.....	8.
Fast Red Salt 3GL.....	(2)	Insoluble azo compound.....	2.
Khaki carbanthrene 2G.....	(2)	Vat dye.....	0.
Naphthol AS-BR.....	(2)	Prepare.....	10.
Nyaform Blue 2B.....	(2)	Direct dye (formaldehyde after treatment).....	Near 0**.
Mixture of 18 dyes.....	(2)	Dyes.....	7.
Dypensol SED.....	(1)	Polyhydric alcohol and cresylates; mercerizing assistant.....	39.
Elvacet.....	(4)	Polyvinyl acetate water emulsions.....	1.
Elvanol 72-60.....	(2)	Polyvinyl alcohol; finishing agent, sizing compound.....	1.
Ethanol.....	(2) (4)	C ₂ H ₅ OH; solvent.....	93*, 125.
Ethyl Acetate.....	(2)	C ₂ H ₅ CO ₂ CH ₃ ; solvent.....	66*.
Experimental 377.....	(6)	Detergent.....	12.
Formaldehyde, 37%.....	(2)	HCHO; shrinkproofing, creaseproofing, modifying dyeing characteristics.....	37.
Formic Acid, 85%.....	(2)	HCOOH; scouring.....	2.
Foryl R 333.....	(6)	Scouring.....	66†.
Globe Easy Flow Starch.....	(6)	Size.....	65.
Gelatin.....	(1)	Gelatin; sizes.....	100.
Glue.....	(1)	Glue, sizes.....	66.
70% Hydroxyacetic acid.....	(6)	HOCH ₂ COOH.....	7.
Hydroxy ammonium sulfate.....	(4)	(NH ₄ OH) ₂ SO ₄	4.
Izepal.....	(2)	Polymerized ethylene oxide alkyl phenol condensation product; detergent, wetting agent, emulsifying, dispersing.....	4.
Ivory Snow.....	(1) (4)	Sodium salt of fatty acid.....	122, 141.
Kyro EO.....	(1)	Polyethylene oxide condensate; synthetic detergent.....	0.
Lanalbine.....	(6)	Protein hydrolyzate; wool protective agent.....	13.
Monochlorobenzene.....	(2)	C ₆ H ₅ Cl; swelling agent in dyeing of Dacron, dyeing assistant.....	3.

Name	Ref.	Composition: use	BOD percent
Morningstar Starch.....	(2)	Starch; sizes, spinning and carding oils.....	47.
Morpholine.....	(2)	O: (CH ₂ CH ₂): NiI ₂ ; dye solvent, emulsifying agent, corrosion inhibitor.	2*.
Nacconol NR.....	(2)	Sodium alkylarylsulfonate; detergent.....	0, 4.
Neutronyx 600.....	(2)	Aromatic polyglycol ether; scouring agent for all fibers....	0.
Nopco 1111.....	(1)	Sulfonated coconut oil; emulsifying agent.....	96.
Nopcolube 55.....	(6)	Synthetic wax for warp sizing.....	80.
Norane W-1.....	(1)	Wax emulsion; water repellent with Norane W-2.....	70.
Orvus EC Paste.....	(3)	Mod. sodium alkyl sulfate type.....	23.
Oxalic Acid.....	(2)	H ₂ C ₂ O ₄ ·2H ₂ O; rust removal.....	14.
Oxytrol.....	(5)	Highly substituted starch.....	15.
Paralube 20 (Tween 20).....	(6)	Anti-static.....	33.
Parval.....	(2)	Fatty amine condensate plus amine soap; scouring, fulling.	5.
Penetrant G.W.....	(6)	Leveling agent.....	14.
Peter Copper Size.....	(1)	Glue; sizes, spinning and carding oils.....	118.
Phenol.....	(1)	H ₂ O; dyeing.....	200.
Picking Oil.....	(1)	Sizes, spinning and carding oils.....	13.
Product BCO.....	(7)	Surface active agent.....	3.
Rapidase M.....	(2)	Amylolytic and proteolytic enzymes; desizing agent.....	4.
Red Oil.....	(2)	Sulfonated castor oil; soapmaking, carding.....	68†.
Resloom NP Special.....	(2)	Melamine-formaldehyde condensate; finishing.....	11, 14.
Rhonite 313.....	(2)	Urea-formaldehyde resin; finishing.....	11.
Rhonite R-1.....	(2)	Modified urea-formaldehyde resin; finishing.....	7.
Salicylic Acid.....	(1)	C ₆ H ₄ (OH)COOH; dyeing.....	141.
Soap, Nonpareil.....	(2)	Fatty-acid soap; scouring, fulling washing.....	140.
Sodium Alginate.....	(2)	Size, thickening agent.....	36.
Sodium Hydrosulfite.....	(2)	Na ₂ S ₂ O ₄ ; reducing, stripping.....	22.
Softener Cream 25%.....	(2)	Sulfonated tallow oil; finishing.....	39.
Special Textile Flakes.....	(2)	Sodium salt of fatty acid; detergent.....	112.
Surfactant DN-40.....	(6)	Scouring.....	15.
Sulfanole KB.....	(3)	Sodium alkylarylsulfonate.....	0.
Sulfonated Castor Oil.....	(1)	Castor oil, sulfonated.....	52.
Sulfuric Acid.....	(1)	H ₂ SO ₄ ; dyeing.....	0.
Stymer S.....	(1)	Styrene maleic anhydrides salt; size, spinning, and carding oils.	1.
Tall Oil Soap.....	(6)	Soap.....	147.
Tallow.....	(2)	Tallow; soap making.....	152.
Tergitol 4.....	(3)	C ₁₂ H ₂₅ CH(C ₂ H ₅)C ₂ H ₄ CH(SO ₃ Na)CH ₂ CH(CH ₃) ₂	0.
Triethanolamine.....	(2)	(HOCH ₂ CH ₂) ₃ N; emulsifier, dispersing agent.....	1; 0.
Triton X-100.....	(1) (5)	Alkylaryl polyether alcohol.....	0.15, 0.2.
Ucon H-6.....	(1)	Polyalkylene glycols; size, spinning, and carding oils.....	4.
Ultrawet 60L.....	(1)	Sodium alkylarylsulfonate; wetting, detergent.....	0.24.
Wheat Starch.....	(2)	Starch; printing inks, size.....	55.
Wool Oil (mineral oil + base).....	(6)	Spinning.....	3.
Zelan AP Paste.....	(2)	High molecular nitrogen compounds; durable water repellent.	19.
Zelec NK.....	(7)	Nondurable antistatic agent.....	54.

*Calculated from the theoretical BOD and the published percent of theoretical.

**The dye color interfered with the determination.

†New biodegradable type.

‡Believed to be low since sample was very old.

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